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ABSTRACT

MathView is a computer algebra system designed to foster interactive exploration of mathematics. MathView is designed so that mathematics, both symbolic and graphic, is highly interactive. Change to a proposition in a MathView notebook produces a cascade of changes to the conclusions that are tied to the proposition. This structure helps to create an environment that encourages experimentation and observation. This paper presents examples of interactive Web pages designed to lead students to discover some of the standard theorems of calculus and discusses the creation of an interactive Web page using MathView. (DDR)

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Interactive Mathematics on the Web--The Easy Way

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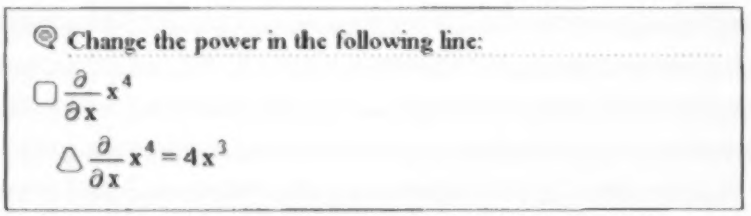
MathView, a product of Waterloo Maple Inc., is a computer algebra system that is designed to foster interactive exploration of mathematics. Unlike other computer algebra systems that are designed to produce one result per command (or click), the MathView interface is designed so that the mathematics–both symbolic and graphic–is highly interactive: a change to a "proposition" in a MathView notebook produces a cascade of instantaneous changes to the "conclusions" that are tied to that proposition. This structure helps to create an environment that encourages experimentation and observation.

Moreover, an interactive environment created in a MathView notebook can be easily embedded in an HTML document and placed on the web. And even though MathView is relatively inexpensive, viewing a web page with an embedded MathView notebook does not even require the MathView system! Instead, all that is required is a plug-in that can be obtained without cost from Waterloo Maple (in addition to a web browser, of course).

This combination of features makes it not only simple, but also highly cost-effective, to create and deliver interactive web-based mathematics. This paper will show examples of interactive web pages designed to lead students to discover some of the standard theorems of calculus, and will also discuss the creation of an interactive web page using MathView.

Examples of MathView Notebooks

In the following simple example, the line beginning with the rounded square icon is a "proposition," and the next line, beginning with the rounded triangle icon, is a



"conclusion." Changing the power in the proposition, say from 4 to 5, causes the conclusion to change immediately to $\frac{\partial}{\partial x} x^5 = 5x^4$. (Note that MathView uses the same

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derivative symbol as its parent software, Maple V.) Moreover, the change in the power is accomplished by simply backspacing over the existing power and typing the new one, so it is quite easy to make numerous changes to the function and observe the result in the derivative.

The notebook shown above can be embedded in a simple web page, as in the following example:

The Power Rule

In the expression below, we are finding the derivative of a *power function*--that is, a function of the form $f(x) = x^n$. Originally the power is 4, and you can see that the derivative is $4x^3$. (Look at the line that begins with the triangle.)

In the line with the square box in front, change the power to various other constant values, and observe how the formula for the derivative changes. Can you detect the pattern? Test your conjecture with negative powers as well as with positive ones, to see if your pattern holds for all constant powers.

Change the power in the following line:

$\square \frac{\partial}{\partial x} x^4$

$\triangle \frac{\partial}{\partial x} x^4 = 4x^3$

With the MathView plug-in installed on your computer, you will be able to interact with the mathematics on this web page in the same way that you would if you were using the MathView software.

As another example, consider the MathView notebook shown on the next page, which is designed to allow students to explore the derivative of a quotient. In this notebook, changing the definition of either f or g will result in an immediate change to the derivative of that function, to the formula for the quotient $\frac{f(x)}{g(x)}$, and to the derivative of the quotient on the last line. Since deleting a portion of the definition of either f or g causes MathView to display any conclusions based on those propositions as crossed out with hash marks, students can easily see which conclusions are affected by the change, and can watch for changes in them to occur. (See the figures on the next page.)

In using web-based material such as this in conjunction with a calculus course, the author provides students with worksheets intended to guide their explorations and lead them to discover the relevant theorems of calculus. Readers who are interested in obtaining copies of these worksheets are encourage to contact the author.

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Change the formulas for f(x) and g(x):

Here is a function f(x) and its derivative:

$f(x) = \sin(x)$

$\frac{\partial}{\partial x} f(x) \quad \triangle \frac{\partial}{\partial x} f(x) = \cos(x)$

Here's another function g(x) and its derivative:

$g(x) = x^5$

$\frac{\partial}{\partial x} g(x) \quad \triangle \frac{\partial}{\partial x} g(x) = 5x^4$

Here is the quotient f(x)/g(x):

$\frac{f(x)}{g(x)} \quad \triangle \frac{f(x)}{g(x)} = \frac{\sin(x)}{x^5}$

And finally, here is the derivative of the quotient.
Can you express it in terms of f(x), g(x), and their derivatives?

$\frac{\partial}{\partial x}\frac{f(x)}{g(x)} \quad \triangle \frac{\partial}{\partial x}\frac{f(x)}{g(x)} = \frac{x^5\cos(x) - 5x^4\sin(x)}{x^{10}}$

Notebook for the Quotient Rule

Change the formulas for f(x) and g(x):

Here is a function f(x) and its derivative:

$f(x) = \sin(x)$

$\frac{\partial}{\partial x} f(x) \quad \triangle \frac{\partial}{\partial x} f(x) = \cos(x)$

Here's another function g(x) and its derivative:

$g(x) = x^5$

$\frac{\partial}{\partial x} g(x) \quad \triangle \frac{\partial}{\partial x} g(x) = 5x^4$

Here is the quotient f(x)/g(x):

$\frac{f(x)}{g(x)} \quad \triangle \frac{f'(x)}{g'(x)} = \frac{\sin(x)}{x^5}$

And finally, here is the derivative of the quotient.
Can you express it in terms of f(x), g(x), and their derivatives?

$\frac{\partial}{\partial x}\frac{f(x)}{g(x)} \quad \triangle \frac{\partial}{\partial x}\frac{f(x)}{g(x)} = \frac{x^5\cos(x) - 5x^4\sin(x)}{x^{10}}$

Quotient Rule Notebook with a Change in Process

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Other examples of interactive MathView notebooks that the author has used in teaching calculus can be viewed on-line at

http://www.jcu.edu/cspitzna/calculus/

In order to be able to view and interact with the mathematics on these pages, it is necessary to install the MathView plug-in on your system. The plug-in can be obtained at no cost from the MathView Internet download site,

http://www.cybermath.com/form_down.html

Versions of the plug-in are available for Windows 95 or NT, Windows 3.1, and Macintosh. The author has tested the Windows 95 plug-in with both Netscape and Internet Explorer.

Creating an Interactive Web Page

Since a MathView notebook that has been embedded in a web page derives its interactive functionality from a plug-in, only the author of the web page needs to have the MathView software. Viewers of the page need only have a web browser with the plug-in installed. Once an appropriate notebook has been created using MathView, in order to embed the notebook in a web page, the notebook must be saved as a .THP file (as opposed to the default notebook file format, .THE). After the notebook has been saved, clicking **Edit Copy HTML Tag** will place a line of HTML code onto the clipboard. An example of this HTML tag is:

```
<embed src="quotrule.thp" height=282 width=692
pluginspage="http://www.maplesoft.com/Products/MathView/Edown.html">
```

A web page to enclose the MathView Notebook can be created using any HTML editor. (The author generally uses Netscape Composer.) Using the source editing feature of the HTML editor, or any ASCII text editor, paste the HTML tag from MathView into the HTML document at whatever location is desired for the notebook to appear.

Several comments about this HTML tag should be made. First, the URL for the pluginspage (the web page that a viewer will be directed to, in case the plug-in has not been installed) has changed, and so it should be changed by hand in this line of HTML code. The correct pluginspage URL is currently:

http://www.cybermath.com/form_down.html

Second, the height and width of the embedded image that are hard-coded into the HTML tag may not be large enough. This is because some of the changes that a viewer might make to the mathematics on the page can increase the horizontal and vertical size of the image needed to contain the mathematics. To assure that the image size allocated by the viewer's web browser is adequate to accommodate the anticipated changes to the

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mathematics, it is recommended that the height–and possibly the width–constants be increased manually when editing the <embed> tag in the HTML document.

After creation of the notebook and the web page to contain it, simply place both files in a location where they accessible to the intended audience. Opening the HTML document with a web browser (which has the MathView plug-in installed) will automatically load the notebook, with all of its interactive functionality.

Conclusion

Although MathView does not have the intrinsic power of many other computer algebra systems, its interface design and plug-in support make it possible to post true interactive mathematics on the web with minimal amounts of effort and cost. In the author's case, MathView has provided the capability to deliver web-based discovery activities for use by students in a calculus class. Interested readers may find examples of these activities on-line, at http://www.jcu.edu/cspitzna/calculus/. Readers are also encouraged to contact the author for written copies of guided discovery worksheets to accompany the interactive calculus web pages.

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